Article

Occurrence and Abundance of Some Non-Indigenous Sparid Species (Actinopterygii: Sparidae) in the Coastal Bulgarian Black Sea Waters

Feriha Myumyunova Tserkova * , Vesselina Vasileva Mihneva * , Elitsa Petrova Petrova-Pavlova , Tihomir R. Stefanov , Krasimir Georgiev Georgiev , Stanimir Todorov Valchev , Zahari Marinov Marinov , Mak Maryanov Goranov , Radinela Radkova Stefanova , Lidiya Zhelyazkova Nedkova

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Occurrence and Abundance of Some Non-Indigenous Sparid Species (Actinopterygii: Sparidae) in the Coastal Bulgarian Black Sea Waters

Feriha M. Tserkova [1,*], Vesselina V. Mihneva [1,*], Elitsa P. Petrova-Pavlova [1], Tihomir Stefanov [2], Krasimir Georgiev [1], Stanimir Valchev [1], Zahari Marinov [1], Mak Goranov [1], Radinela Stefanova [1] and Lidia Nedkova [1]

[1] Agricultural Academy, Institute of Fish Resources; elitssa@yahoo.com (E.P.P.-P.); krasi2g@gmail.com (K.G.); stanimirvalchev@abv.bg (S.V.); z.marinov@bizarreaqua.com (Z.M.); mak.goranov@gmail.com (M.G.); r.stefanova@ifrvarna.com (R.S.); lidia.nedkova@gmail.com (L.N.)

[2] Bulgarian Academy of Sciences, National Museum of Natural History; tishos@gmail.com

* Correspondence: feriha.tserkova@ifrvarna.com (F.M.T.); vvmihneva@yahoo.com (V.V.M.)

Abstract: Fish species diversity in the Black Sea is affected by the introduction of non-indigenous species, particularly through the process of "mediterranization" and the expansion of the ranges of invasive species. In August 2023, we documented an increasing quantity of four non- indigenous sparid species, namely *Spicara smaris* (Linnaeus, 1758), *Diplodus puntazzo* (Walbaum, 1792), *Diplodus annularis* (Linnaeus, 1758), and *Lithognathus mormyrus* (Linnaeus, 1758), in the coastal Bulgarian waters of the Black Sea, based on citizen science data obtained from small-scale fisheries and pelagic trawlers. However, in the autumn of 2022, only small quantities of *S. smaris* were collected periodically, indicating significant fluctuations in abundance and occasional presence. The other three species were recorded in August 2023 in the central coastal region near the Fandakliyska River, at depths of less than 10 m. This brief communication presents information on the identified species, including sampling locations and biological data, and examines the sparid species records in the Black Sea. In addition, we reviewed recent studies on the distribution and biological traits of the identified species in their natural Mediterranean habitats.

Keywords: mediterranization of Black Sea; non-indigenous Sparid fish; fish species biodiversity

Key Contribution: Citizen science data gathered from small-scale fisheries and pelagic trawlers operating in the coastal waters of the Black Sea in Bulgaria unveiled the presence of four non-indigenous sparid species: *Spicara smaris*, *Diplodus puntazzo*, *Diplodus annularis*, and *Lithognathus mormyrus*. The highest catch of these species was recorded In August 2023, whereas *S. smaris*, the most frequently observed species, was found in small quantities in 2022, with significant fluctuations in abundance. *S. smaris* was primarily detected along the central and southern coasts at depths less than 50 m. Only records of the other three species have been discovered in shallow waters close to the mouth of Fandakliyska River. We analysed the records of these sparid species in the Black Sea and reviewed their distribution and biological characteristics in natural Mediterranean habitats.

1. Introduction

The Black Sea, a basin distinguished by low-salinity waters and anoxic conditions below 200 m, exhibits higher productivity than the Mediterranean Sea, yet supports a lower level of biodiversity. The fauna of the Black Sea comprises a complex and dynamic assemblage of indigenous and immigrant species, reflecting the region's geological, climatic, and anthropogenic influence. A limited

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variety of species facilitates the introduction of exotic invaders and renders biodiversity particularly vulnerable to bioinvasion [1–4].

The concept of "mediterranization" refers to the increasing presence and impact of Mediterranean species in the Black Sea ecosystem. This phenomenon is attributed to the introduction of non-indigenous species (NIS) by human activities such as ballast water from ships and intentional or unintentional release. Moreover, the natural dispersal of species through the Bosphorus Strait, which connects the Black Sea and Mediterranean Sea, as well as climate change, which affects environmental conditions and biogeographical boundaries, also contribute to this process [2,4].

The connection between the Black Sea and Mediterranean Sea has been subject to numerous interruptions and reconnections owing to fluctuations in sea levels, climatic shifts, and geological processes, as documented by the geological history of the area. As a result, the Black Sea has transformed into a brackish sea and numerous species have emerged or evolved in this region. The process of Mediterranean fauna penetrating the Black Sea is ongoing. Occasionally, Mediterranean Sea species previously unobserved in the Black Sea were discovered in this region [5]. The current fish fauna in the Black Sea comprises of approximately 190 species [6]. Analysis of the geographic origins of marine fish species indicated that the majority (59.26%) had an Atlantic-Mediterranean origin, 7.41% were cosmopolitan in nature, 31.22% were Ponto-Caspian relics (endemic to the region), and 2.12% were introduced from the Indo-Pacific and European waters [6].

The number of alien species in the Black Sea has recently increased, raising concerns regarding their potential impact on indigenous fish populations and ecosystems [7]. Notably, records of NIS species in the Black Sea have included members of the Sparidae family, which comprises approximately 150 species in 37 genera [8], and is primarily found in shallow temperate and tropical waters. NIS Sparid species are more commonly found along the Turkish coast and may play a role in local fisheries. Despite the expansion of Sparidae's range to the Black Sea, there is a scarcity of information on these fish species and their abundance, particularly in the Bulgarian sector. Consequently, citizen science could be a valuable tool for collecting data and monitoring the distribution of non-indigenous species.

In this study, we used citizen science from both small-scale fisheries and pelagic trawlers to expand data collection and engage the public in the scientific process. These data indicate the presence of four non-indigenous species of Sparidae fish in the coastal waters of the Bulgarian Black Sea sector during autumn 2022 and the warm season of 2023. The aim of this brief communication was to provide information on non-indigenous Sparidae species in Bulgarian Black Sea waters and summarize their previous sightings in the Black Sea. Furthermore, we reviewed recent studies on the distribution and biological traits of the identified species in their natural Mediterranean habitats.

2. Materials and Methods

This study implemented a research strategy developed by the Institute of Fish Resources with Aquarium in Varna, Bulgaria, which incorporates citizen science data (properly documented and accompanied by live samples or photographs) obtained from small-scale fisheries and pelagic trawlers between 2022-2023. This approach facilitated the identification of non-indigenous Sparidae species in Bulgarian Black Sea waters during the periods September-November 2022 and August-October 2023 (Figure 1).

The samples were collected using small fishing boats with passive fishing gear and a mesh size of 32 × 32 mm at depths of 1-10 meters along the central Bulgarian coast (near Byala and Kara Dere), as well as from pelagic trawlers operating at depths ranging from 25 m to 45 m (between C. Kaliakra and Tsarevo). The trawlers were equipped with midwater otter trawls (OTM) with mesh sizes of 16 × 16 mm and 18 × 1 8 mm. The lengths and weights of the specimens were measured onboard the fishing vessel.

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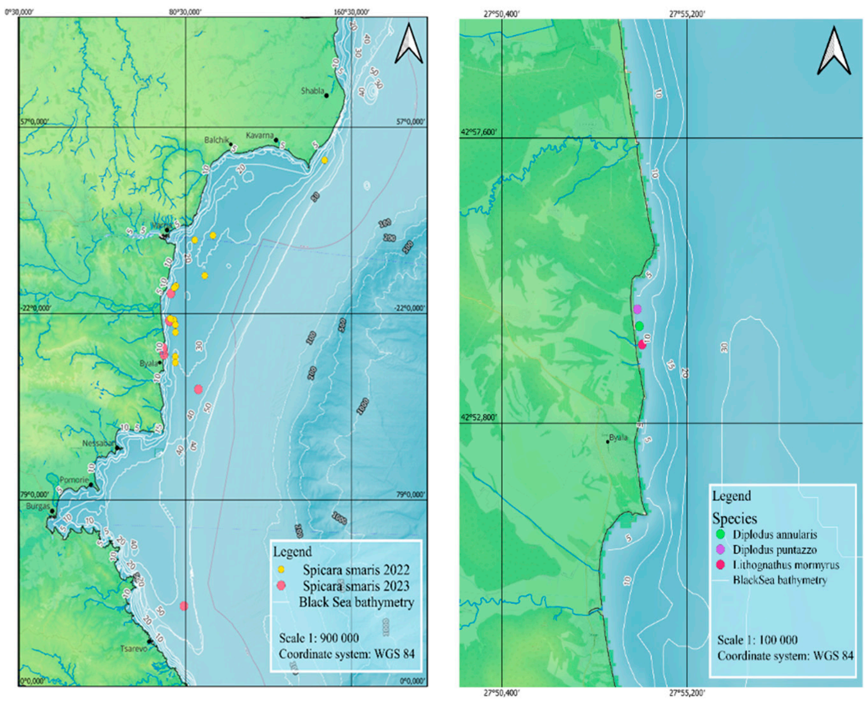

a) b)

Figure 1. Map of the Bulgarian Black Sea sector, including locations of the collected Sparidae fish (a) localities of *S. smaris* in 2022-2023 and (b) localities of *L. mormyrus*, *D. annualis*, and *D. puntazzo* in 2023.

3. Results

This study, conducted during the summer-autumn seasons of 2022-2023, documented the presence and increasing quantities of four non-indigenous species in coastal Bulgarian Black Sea waters: *Spicara smaris* (Linnaeus, 1758), *Lithognathus mormyrus* (Linnaeus, 1758), *Diplodus puntazzo* (Walbaum, 1792), and *Diplodus annularis* (Linnaeus, 1758) (Table 1, Figures 1 and 2).

Among them, *S. smaris* was the most frequently observed NIS species. This species was identified at 16 different locations, mostly along the central and southern coasts, with quantities ranging from 0.01 to 60 kg and medium sizes ranging from 7.9 to 12.4 cm in length and 5.61 to 19.9 g in weight. *S. smaris* was recorded mostly at depths < 30 m. It should be noted that *S. smaris* quantity was very low during the observations in autumn of 2022, within the ranges of 0.01 to 0.05 kg, indicating a large fluctuation in the species' abundance and the possibility of occasional presence only.

Table 1. Citizen science data for identified non-indigenous sparid species, including sampling dates, coordinates, depths, catch quantities, mean length, and mean weight per locality.

NIS Fish species	Finding date	Fishing gear mesh size	Coordinates		Depth (m)		Catch quantity (kg)	Mean Length (cm)	Mean weight (g)
			Latitude	Longitude					
S. smaris	13.09.2022	16/16 mm	43.193	28.061	18	21.4	0.01057	7.9	5.61
	1.11.2022	16/16 mm	42.982	27.926	26.5	27.1	0.01666	9.5	8.33
	1.11.2022	18/18 mm	42.970	27.947	27	23.4	0.00846	9.6	8.46
	2.11.2022	16/16 mm	43.067	27.949	24.7	27.8	0.00884	9.7	8.84
	2.11.2022	18/18 mm	43.063	27.942	24	29	0.00622	8.6	6.22

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	10.11.2022	16/16 mm	43.182	28.022	23.3	23.2	0.03335	8.84	6.67
	11.11.2022	18/18 mm	42.951	27.947	27.2	24.4	0.02146	8.9	7.15
	15.11.2022	16/16 mm	43.381	28.527	32.6	32.4	0.00711	8.9	7.11
	18.11.2022	18/18 mm	42.890	27.946	32.9	30.5	0.04728	9.2	7.73
	31.8.2023	16X16 mm	42.979	27.925	25	26.2	40.95	12.3	19.12
	31.8.2023	16X16 mm	42.978	27.924	24.9	26.4	7.23	12.3	19.9
	31.8.2023	16X16 mm	43.048	27.929	26.2	25	6	12.4	18.8
	31.8.2023	16X16 mm	42.980	27.923	25.1	26.1	4	12.2	19.66
	31.8.2023	32/32 mm	42.895	27.902	1	5	60	12.4	18.96
	6.10.2023	16X16 mm	42.261	27.980	43.3	42	28.5	11	14.32
	13.10.2023	16X16 mm	42.808	28.036	32.1	35.5	7.1	10.93	14.25
L. mormyrus	28.8.2023	32/32 mm	42.902	27.901	1	5	20	20	107
D. puntazzo	30.8.2023	32/32 mm	42.912	27.899	1	5	60	22.3	167.8
D. annularis	29.8.2023	32/32 mm	42.907	27.899	1	5	50	19.7	114

Figure 2. Non-indigenous Sparidae fish found in 2023: A) *L. mormyrus*, B) *D. puntazzo*, C) *S. smaris*, and D) *D. annularis*. (The Aquarium Varna received live fish specimens that were subsequently photographed).

Spicara smaris is commonly referred to as the picarel and is endemic to the Mediterranean Sea and eastern Atlantic Ocean. Greyish-above and silvery-below colouration vary according to factors such as age, sex, and season [9,10]. *S. smaris* inhabits muddy and rocky bottoms, as well as seagrass beds, with juveniles preferring seagrass beds as nursery areas [11–13]. It is classified as an omnivorous species, with a diet comprising zooplanktonic crustaceans, meroplanktonic larvae, and fish larvae [14]. The species can reach a maximum length of 21.24 cm [15], although the most commonly observed sizes in the Black Sea are 11.5 - 14.0 cm [16].

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This species was initially discovered in the Black Sea near the coast of Türkiye by [17] and was later reported by [16,18,19]. *S. smaris* was first reported on the Bulgarian Black Sea coast by [20], a single specimen collected near Cape Galata, Varna District (Table 2). However, in recent years, their range and abundance have expanded and the species has periodically been found off the coasts of Bulgaria, Romania, and Russia. This species is more abundant along the eastern coast of Türkiye, where it contributes to commercial fisheries, with catch doubling between 1976 and 1991 [16]. Found at depths ranging from 15 m to 170 m [16], mainly in the upper layer, *S. smaris* can compete with native fish species for food and space, and may also prey on their eggs and larvae.

Table 2. Summarized data on discoveries of non-indigenous Sparid species in Black Sea.

Species	**Location of Detection**	**Year of Discovery**	**Reference**
Spicara smaris	Coast of Türkiye	1860-1964	[17,18]
	Cape Galata, Varna (Bulgaria)	1952	[20]
	Coast of Türkiye from Sinop to the Georgian border	1991 and 1992	[16]
	Sinop (Türkiye)	2018	[19]
Lithognathus mormyrus	Varna Bay	1958	[21]
	Romania-Bulgaria	1980-2013	[5,22–24]
	Varna (Bulgaria)	2007	[5]
	Near the mouth of the Hosta River, Matsesta R., Kudepsta R., Mzymta R. (Russia)	2007	[5]
	Sukhumi, Pitsunda (Ab-khazia)	2013	[5]
	Cape Aya (Crimea)	2013	[5,24,25]
	Crimea	2013	[26]
	Çamburnu Harbour-Trabzon (Türkiye)	2013	[27]
	Arhavi-Artvin (Türkiye)	2013	[27] Engin et. al. (2015)
	Derepazarı-Rize (Türkiye)	2013-2014	[27] Engin et. al. (2015)
	Pazar-Rize (Turkiey)	2013	[27] Engin et. al. (2015)
	Rumeli Feneri-İstanbul (Türkiye)	2013	[27] Engin et. al. (2015)
	Sinop (Türkiye)	2013	[28] Satilmis et. al. (2014)
	Kobuleti (Georgia)	2014	[25] Guchmanidze and Boltachev (2017)
	Dzhubga (Russia)	2014	[5] Guskov (2021)
	Sevastopol (Crimea)	2014	[5] Guskov (2021)
			[25] Guchmanidze and
	Aya Cape (Crimea)	2015	Boltachev (2017)
			[29] Kasapoğlu et. al. (2020)
	Trabzon (Türkiye)	2015	[25] Guchmanidze and
	Kazachya Bay (Crimea)	2016	Boltachev (2017)
			[26] Gus'kov et. al. (2022)

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	Caucasus	2016	[5] Guskov (2021)
	Yalta (Crimea)	2016	[5] Guskov (2021)
	Lazarevskoe (Russia)	2016	[5] Guskov (2021)
	Gelendzhik (Russia)	2017	[30,31] Aydin (2018), Aydin
	Ordu (Turkiey)	2017-2018	and Sözer (2019)
			[5] Guskov (2021)
	Novorossiysk (Russia)	2019	[5] Guskov (2021)
	Maly Utrish (Russia)	2019	[5] Guskov (2021)
	Sukko (Russia)	2019	[5] Guskov (2021)
	Karadag biological station	2019	
	(Crimea)		[5] Guskov (2021)
	Ordzhonikidze (Crimea)	2020	[32] Karadurmuş and Aydin
	Turkish coast	2020	(2021)
Diplodus puntazzo			[33] Maltsev et. al. (2020)
	South-Eastern Crimea	-	[34] Drensky (1948)
	Near Burgas (Bulgaria)	1948	[35] Drensky (1951)
	Near Sozopol (Bulgaria)	1950	[21,36,37] Gueorguiev et al.
	Bulgarian Black Sea coast	1960-1970	(1960), Stojanov et al. (1963),
			Manolov (1970)
			[38] Bat et. al. (2005)
	Sinop and Samsun (Türkiye)	between January 1998	
		and February 2003	[39] Boltachev et. al. (2009)
	Crimea	from 1999 to 2008	[40] Papadopol et. al. (2016)
	Agigea (Romania)	2016	[41] Aydin and Saglam (2019)
	Hopa region (Türkiye)	2017	[42] Aydın and Özdemir
	between Sinop and Hopa	between April 2018	(2021)
	(Türkiye)	and March 2019	
	Ordu (Türkiye)	2019	[43] Aydin (2019)
Diplodus annularis	Black Sea from Balchik to	1923-1951	[34,35,44] Drensky (1923,
	Sozopol (Bulgaria)		1948,1951)
	Bulgarian Black Sea (rare	1960-1970	[21,37] Stojanov et al., 1963;
	presence)		Manolov, 1970
		between	[45] Samsun et. al. (2017)
	Central Black Sea, Sinop	September 2016 and	
	(Türkiye)	February 2017	

S. smaris is a protogynous sequential hermaphrodite fish, indicating that individuals first mature as females and later can become males. According to [46], the spawning season of *S. smaris* in the Mediterranean region begins in February and ends in May. [47] study, conducted in the Eastern Black Sea, found that the spawning season in this area was between May and June. This difference in spawning seasons is attributed to a variety of factors, including habitat conditions and food

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availability. We found small individuals with length of 7.9-9.2 cm, indicating the possibility of local reproduction of *S. smaris*.

Lithognathus mormyrus, referred to as the Atlantic striped sea bream, sand steenbras, or sand smelt, is a demersal marine species commonly found in the Mediterranean Sea, Atlantic Ocean, Southwestern Indian Ocean, and the Red Sea [48]. *L. mormyrus* is a non-indigenous species of Mediterranean origin that was first discovered in the Black Sea in 1958 near Varna Bay, as reported by [21]. Subsequently, this species was recorded along the coasts of Bulgaria and Romania during the 1980s [22–24] (Table 2). More recent findings by [24] and [26] revealed the presence of this species on the South Coast of Crimea and near Cape Aya. Atlantic striped bream has also been reported on the coast of Türkiye [27–29,31,32,49] and off the Caucasus coast [25,50]. This species has been observed in the coastal waters of the southeastern Crimea, specifically within the protected region of the Karadag Nature Reserve [33]. The recent adaptation of this species to the conditions of the Black Sea has been demonstrated by the presence of juveniles in Cossack Bay off the coast of Sevastopol and spawned individuals off the coast of Abkhazia [51,52]. Furthermore, according to [5], Atlantic striped sea bream is found under estuarine conditions near large rivers.

According to our records, a significant increase in the quantity of *L. mormyrus* was observed in the coastal waters around Byala at depths of < 10 m near the mouth of the Fandakliyska River in August 2023. The catch of this species was 20 kg with an average length and weight of 20 cm and 107 g, respectively. [53] reported that the asymptotic length of this species is 30.18 cm in the Gulf of Tunis. *L. mormyrus* is found at depths ranging from 0 to 150 m, with a preference for water between 10 and 30 m [54]. The preferred habitats of striped sea bream are rocky and sandy bottoms, and seagrass beds. In the Mediterranean region, it is commonly found in estuaries and lagoons, where juveniles often find essential nursing habitats [48].

Striped sea bream primarily consumes teleosts, crustaceans, molluscs, echinoderms, annelids, spongia and plantae and its diet vary across different life stages [55,56]. The species is a protandric hermaphrodite, indicating that some individuals change sex from male to female during their lifetime. Males reach sexual maturity at 16.21 cm (2.5 years), and females at 19.04 cm (3.6 years) [57]. [58] research from the Mediterranean Sea surrounding Eastern Libya concluded that the breeding season for the striped seabream is between May and August. In contrast, [59] findings indicate that the population in the Köyceğiz Lagoon, Türkiye, reproduces from late April until early June, which aligns with [60] results from Baymelek Lagoon, Türkiye. In the coastal waters of the Thracian Sea, Greece, the spawning period of striped sea bream ranges from May to September, with gamete emissions peaking in June-August [57]. Recent research has suggested a potential increase in *L. mormyrus* populations in the Black Sea [33]. Although this species has been noted to reproduce in the Black Sea, further research is needed to determine the spawning period in this basin [29].

Diplodus puntazzo, referred to as the sharpsnout seabream, has been observed in the coastal waters of Türkiye according to studies conducted by [38,41–43]. It is considered a rare and temporary inhabitant of the Bulgarian Black Sea coastal waters [21,34–37]. It is worth to note that the sharpsnout seabream can also be found off the coasts of Crimea [39] and Romania [40] (Table 2). During the current observations, a single catch of D. *puntazzo* with a weight of 60 kg, mean length of 22.3 cm and weight of 167.8 g was documented (Table 1). The location where this catch was made was close to Byala and the Fandakliyska River at a depth of less than 10 m.

Typically, *D. puntazzo* can grow to a maximum length of 60 cm, but it is mostly approximately 30 cm long [61]. In the eastern Adriatic Sea, the asymptotic length of this species is estimated at 45.28 cm [62]. Its diet is comprised of Plantae, Spongia, Tunicata, Echinodermata, Crustacea, Annelida, Mollusca, and Teleostei, with plants being the most important food source [63]. The species is found throughout the Mediterranean basin, including in the Strait of Gibraltar and the Adriatic, Aegean, Ionian, and Levantine Seas.

Similar to other Sparidae species, they are hermaphrodites. Young individuals are male, and after maturity they can transform into females. In its natural habitat, D. *puntazzo* spawns in the coastal waters between October and March [64]. Adults of this species usually reside in surf zones, with their preferred habitats being rocky bottoms and seagrass beds [63]. However, juveniles are also found in

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lagoons, brackish waters, and littoral pools [65]. The spawning times of species vary depending on the area they inhabit. For example, [66] noted that September through February was the reproductive period for the species off the Canary Islands. According to research conducted by [64], specimens from the Gulf of Tunis, Central Mediterranean, reproduce from September to December. [62] found that the spawning period of sharpsnout seabream in the Adriatic Sea occurred between August and October. Similarly, in a 2021 study by [41] on a southern Black Sea D. *puntazzo* population, the spawning period was found to be from August until November.

Diplodus annularis, referred to as annular seabream, is widely distributed in the eastern Atlantic and Mediterranean Seas [54]. This demersal fish species inhabits seagrass beds in shallow waters ranging from 0 to 50 m in depth [61], with a preference for Posidonia beds [67].

Based on a study by [45], *D. annularis* was observed in Sinop, Türkiye (Table 2). It was previously known as a common species along the Bulgarian coast of the Black Sea near Balchik, Varna, Nessebar, Pomorie, Burgas, and Sozopol [34,35,44]. Later, it was considered a rare summer visitor to Bulgarian Black Sea waters [21,37]. The current observations detected *D. annularis* in the central part of Bulgarian waters near the Fandakliyska River and Byala (at depths <10 m), with a catch quantity of 50 kg, mean lengths of 19.7 cm, and weight of 114 g.

As an omnivorous diurnal feeder, it primarily feeds on Mollusks, Teleosts, and small crustaceans [68–70]. Previous studies designated *D. annularis* as a protandrous species. However, recent findings by [71]. (2011) revealed a reproductive phenomenon known as non-functional hermaphroditism in this species. In this case, both male and female reproductive tissues are present, but do not function simultaneously, differing from sequential and simultaneous hermaphroditism, in which the reproductive tissues of both sexes are active at some point.

The spawning period of annular seabream varied between regions. [67] concluded that annular seabreams from the Gulf of Gables, Central Mediterranean, were reproducing from March to June. The spawning period for this species from the southern coast of Mallorca, northwestern Mediterranean Sea, peaks in May and June [71]. In contrast to the late spring-early summer breeding period demonstrated by [71], in the Central-Western Mediterranean Seas *D. annularis* has been noted to reproduce in late winter-spring, peaking between April and May [72]. The populations in the Adriatic Sea start spawning from the end of April and continue until the end of August, as reported by [73]. Variations in spawning times among populations can be attributed to differences in habitat conditions, with a special emphasis on the effects of temperature and food availability [67]. Further studies are required to investigate the reproductive cycle of *D. annularis* in the Black Sea.

4. Discussion

Non-indigenous fish species can have a range of impacts on the native biodiversity, ecosystem functioning, and human well-being of invaded regions, which are determined by their ecological traits, interactions, and environmental conditions. These impacts include increased competition, predation on local fish species, increased herbivory, transmission of parasites or diseases that can affect native fish species, and hybridisation, which can influence the genetic integrity and diversity of native populations [74–76]. Some non-indigenous fish species have the potential to become invasive, establish populations, proliferate, and have ecological and economic effects on native species and fisheries [3].

Over the past few decades, the discovery of 28 new fish species [7] in the Black Sea has demonstrated the effects of both the "mediterranization" process and the accidental introduction of exotic species of Indo-Pacific origin on fish species diversity [6,39,77]. Moreover, some species have already expanded their range, such as *Sarpa salpa*, which was first detected along the southwestern coast of Crimea in 1999 and has since become a common species in this region [24,78,79].

Turkey's coastal regions host NIS Sparid species more frequently, which may have implications for the local fishing industry. According to the citizen science data collected in this study, *S. smaris* appears to be the most frequently observed NIS species in 2022-2023, detected at 16 locations, primarily along the central and southern Bulgarian Coast. We observed an increase in the quantity of identified Sparid species in the central part of the Bulgarian coast in August 2023 (up to 60 kg), compared to the autumn season of 2022, when only *S. smaris* was detected with a maximum catch of 0.05 kg. Notably, high oscillations in abundance suggest the occasional presence of this species along the Bulgarian coast. However, the presence of small individuals also provides options for local reproduction. Additionally, single records of *L. mormyrus*, *D. puntazzo*, and *D. annularis* were discovered in shallow waters close to the Fandakliyska River at depths of less than 10 m, but their catches were not low, and ranged between 20-60 kg per species.

The identified Sparidae fish were classified as omnivorous and hermaphroditic, which may provide certain advantages over the native species. Furthermore, their ability to adapt to the Black Sea's climatic changes is facilitated by the region's projected warming, with a maximum increase in sea surface temperature with 2.81-0.53°C per century in summer [80]. The effects of climate change may support the introduction of new species and adaptation of existing species, potentially affecting physiology, migration, aggregation formation, food availability, and reproduction processes. The Black Sea ecosystem is highly susceptible to both environmental and anthropogenic stressors [81], and increased overfishing pressure can render fish stocks more vulnerable to future climate change and potential biological invasions.

Finally, it is crucial to recognize that non-indigenous species can offer prospects for profitable utilization, transforming environmental issues into economic advantages. For example, the Muricidae snail *Rapana venosa*, which was introduced to the Black Sea from the Japan Sea in the 1940s, has emerged as a valuable target for local fishing industries, generating a new revenue stream [82]. Managing non-indigenous species in marine ecosystems can help to sustainably utilise their commercial potential without causing ecological disturbances.

5. Conclusions

Four non-native sparid species, *Lithognathus mormyrus*, *Spicara smaris*, *Diplodus puntazzo*, and *Diplodus annularis*, were monitored through citizen science data collection obtained from small-scale fisheries and pelagic trawlers operating along the Bulgarian coastline of the Black Sea. The highest catch of these species was recorded in August 2023, weighing–20-60 kg per species. While *S. smaris* was the most frequently observed NIS species, with 16 detections during warm months of 2022-2023, its quantity fluctuated significantly in this period, with possibility of occasional presence only. The species was detected primarily along the central and southern Bulgarian coasts, with catch ranging from 0.01 to 60 kg and mean lengths ranging from 7.9 to 12.4 cm.

The other Spridae species, *L. mormyrus*, *D. puntazzo*, and *D. annularis*, were documented with single catches in August 2023 in central coastal regions at depths of less than 10 m, particularly close to the Fandakliyska River. The identified Sparidae are omnivorous and hermaphroditic fish, providing certain advantages over native species. These fish can adapt to the projected warming of the Black Sea, particularly considering that their reproductive processes are influenced by temperature and food availability. Effective management is essential for capitalising on the commercial potential of non-native species.

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